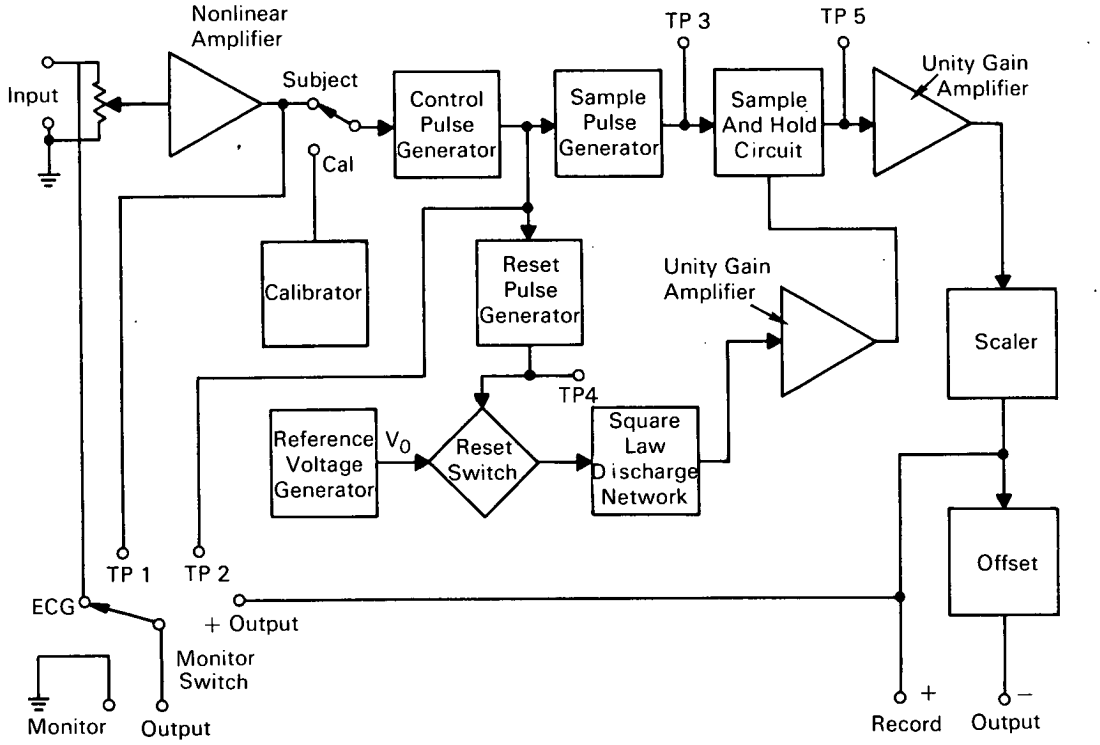
NASA TECH BRIEF

Cardiotachometer with Linear Beat-to-Beat Frequency Response



The problem:

To develop an instrument that will continuously detect and immediately display, to a high order of accuracy, the heart rate of human subjects and larger animals during physiological studies. The system, to be versatile, should have a linear response, a great enough range to record heart rate of a subject during rest and under heavy stress, provide a beat-to-beat indication of changes in heart rate rather than an average over several cycles, and should be relatively free of interfering signals from activities other than the heart rate.

The solution:

A cardiotachometer employing a nonlinear amplifier together with an exponential (square law) resistor and a capacitor which form a square law discharge network, making possible a linear response to the heart rate. Suitable clipping and filtering minimize interfering signals. Solid state circuitry assures reliable operation, and even in cases of severe arrhythmia, the instrument follows changes in beat-to-beat frequency with an accuracy of ±1 beat per minute. The cardiotachometer is designed to accept input

(continued overleaf)

pulses derived from recordings of the electrocardiogram, plethysmogram, or blood pressure wave.

How it's done:

The heart rate is recorded linearly, by measuring the time interval between successive pulses and converting it into a voltage proportional to the reciprocal of the interval. This is accomplished by charging a capacitor to an initial reference voltage at the beginning of each time interval and after a fixed time delay, discharging the capacitor through a resistive element with characteristic current flow proportional to the square of the applied voltage (square law element). The capacitor voltage at any time after discharge begins is proportional to the input frequency. The following requirements were met for this application.

a. A range of 30 to 270 beats per minute.
b. An overall accuracy of ±1 beat per minute over the linear operating range.
c. A beat-to-beat output response that follows a rapidly varying input rate within the ±1 beat accuracy specification.
d. Reliable operation when used with moderately active subjects.

The cardiotachometer is designed for use with an input pulse of approximately 0.2 volt. Recordings with the instrument of tests on subjects doing sit-up exercises and running in place demonstrated reliable operation with moderately active subjects. Accurate beat-to-beat output responses within the ±1 beat per minute specifications were demonstrated even on subjects with pronounced arrhythmia.

Notes:

1. The cardiotachometer can easily be modified to operate at higher frequency ranges and still retain its linear beat-to-beat characteristics. For major frequency changes, the bandpass characteristics of the nonlinear amplifier would have to be modified.
2. The accuracy of this method depends on the accuracy of the square law element.
3. The introduction of clipping and coupling and bypass networks in the nonlinear amplifier allows transmission of the peaks of the R wave in the ECG while minimizing the transmission of baseline shifts and other unwanted signals. Optimal triggering of the instrument was achieved with a bandpass of approximately 8 to 40 Hz. It might be desirable to restrict the bandpass further for subjects under very strenuous exercise.
4. To obtain a reliable trigger pulse under a variety of experimental conditions, a monitor selector switch allows the experimenter to monitor the trigger pulse at several test points within the circuitry. Thus, the pulse can be precisely adjusted within the circuitry to give optimal trigger reliability.
5. Calibration of the instrument is provided for by the inclusion of a conventional unijunction transistor pulse generator with selectable rates of 60, 80, 120, 180, and 240 pulses per minute. These calibrated pulse rates can be inserted into the system in place of the normal input signal.
6. Additional details are contained in *A Cardiotachometer with Linear Indication of Beat-to-Beat Frequency*, by Jack M. Pope, Gordon J. Deboo, and David B. D. Smith, Ames Research Center. Copies of this paper are available from:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B67-10598

Patent status:

No patent action is contemplated by NASA.

Source: J. M. Pope, G. J. Deboo, and D. B. D. Smith (ARC-10033)